Health Promotion and Chronic Disease Prevention in Canada

Research, Policy and Practice

Volume 37 · Number 2 · February 2017

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ISSN 2368-738X
Pub. 160268
Journal_HPCDP-Revue_PSPMC@phac-aspc.gc.ca

Également disponible en français sous le titre : *Promotion de la santé et prévention des maladies chroniques au Canada : Recherche, politiques et pratiques*

Submission guidelines and information on article types are available at: http://www.phac-aspc.gc.ca/publicat/hpcdp-pspmc/authinfo-eng.php

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Canada

Editorial

The weight of our nation

Hans Krueger, PhD (1,2)

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Canadians spent an estimated $228 billion on health care in 2016. That represents 11.1% of our total economy, or $6,299 per person. Almost 40% of all public expenditures are allocated to fund health care.[1] Put succinctly, that is a lot of money! This issue of *Health Promotion and Chronic Disease Prevention in Canada* places a spotlight on three diseases that contribute to this economic burden of health care in Canada.

Pelletier and coauthors[2] estimate that 700 000 Canadians report symptoms consistent with generalized anxiety disorder (GAD) and that 30% of these individuals' needs for health care are not being met. Amankwah and colleagues[3] estimate that 99 000 Canadians were living with multiple sclerosis (MS) in 2011 and that this number will increase to 134 000 by 2031. Estimated health care and out-of-pocket costs attributable to MS in 2011 were $1.48 billion.

Bilandzic and Rosella[4] calculate that 2 156 000 new cases of diabetes will be diagnosed in Canada during the 10-year period between 2011/12 and 2021/22, with attributable health care costs of $15.36 billion, or $7,124 per individual with diabetes. They further calculate that 283 000 cases of diabetes and $2.03 billion in costs could be avoided if the average body weight of Canadians were reduced by 5%.

The focus on the relationship between diabetes and excess weight by Bilandzic and Rosella is appropriate as we estimate that 62% of type 2 diabetes in Canada is attributable to excess weight.[5] A further 18% and 8%, however, is attributable to physical inactivity and tobacco smoking, respectively. Based on Canadian Community Health Survey (CCHS) data, the prevalence of tobacco smoking was reduced from 24.8% to 16.2% between 2001 and 2014 among Canadians aged 20 to 64 years. Similarly, the prevalence of physical inactivity has been reduced from 55% to 47%. The biggest challenge, however, remains with excess weight. During that same time period, the prevalence of obesity increased from 15.3% to 20.6% (or a total of 4 557 000 Canadians). Most importantly, the prevalence of individuals with the highest levels of obesity has more than doubled. Both the health and economic burdens associated with obesity increase dramatically as weight increases.

The diverging trends in the prevalence of tobacco smoking and excess weight in Canada means that the economic burden attributable to excess weight is now 25% higher than that attributable to tobacco smoking.[5] This crossover occurred in 2009, and the gap between the economic burden attributable to excess weight and tobacco smoking has continued to widen.

Success in reducing the prevalence of tobacco smoking resulted in a 34% *decrease* in the attributable economic burden in Canada between 2000 and 2015, while the economic burden attributable to excess weight *increased* by 24%. Within this context, how might we be able to achieve even the modest 5% reduction in weight suggested by Bilandzic and Rosella? Can we apply any of the lessons learned from the success addressing tobacco smoking to excess weight? During the last 60 years, we have learned that progress in the prevention of tobacco smoking has taken a comprehensive, long-term approach involving price increases (usually through taxation), controlling the advertising of tobacco products, counter-advertising, enhanced clinical cessation strategies and clean air legislation (smoking bans).[6]

While progress in the prevention of tobacco smoking has been challenging, and there is still much work to be done, addressing excess weight is likely to be even more complex. At its simplest, excess weight involves an imbalance of energy intake and output, but there is a much more complicated web of causal factors influencing weight-related problems.[7] Organizations such as the World Health Organization[8] and the Centers for Disease Control and Prevention in the US[9] have begun to suggest a series of strategies to address excess weight, including the need to measure and evaluate obesity prevention efforts. What we do know is that the ability to successfully address excess weight at the population level will require a comprehensive, multidimensional approach in numerous spheres for at least a generation, with positive lifestyle choices consistently being reinforced by a supportive environment.[6]

The health of our nation, and our economy, requires that such a comprehensive, long-term approach be implemented now. We can no longer afford to wait.

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Multiple sclerosis in Canada 2011 to 2031: results of a microsimulation modelling study of epidemiological and economic impacts

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Abstract

Introduction: The objective of our study was to present model-based estimates and projections on current and future health and economic impacts of multiple sclerosis (MS) in Canada over a 20-year time horizon (2011–2031).

Methods: Using Statistics Canada's Population Health Microsimulation Model (POHEM) framework, specifically the population-based longitudinal, microsimulation model named POHEM-Neurological, we identified people with MS from health administrative data sources and derived incidence and mortality rate parameters from a British Columbia population-based cohort for future MS incidence and mortality projections. We also included a utility-based measure (Health Utilities Index Mark 3) reflecting states of functional health to allow projections of health-related quality of life. Finally, we estimated caregiving parameters and health care costs from Canadian national surveys and health administrative data and included them as model parameters to assess the health and economic impact of the neurological conditions.

Results: The number of incident MS cases is expected to rise slightly from 4051 cases in 2011 to 4794 cases per 100 000 population in 2031, and the number of Canadians affected by MS will increase from 98 385 in 2011 to 133 635 in 2031. The total per capita health care cost (excluding out-of-pocket expenses) for adults aged 20 and older in 2011 was about $16 800 for individuals with MS, and approximately $2500 for individuals without a neurological condition. Thus, after accounting for additional expenditures due to MS (excluding out-of-pocket expenses), total annual health sector costs for MS are expected to reach $2.0 billion by 2031. As well, the average out-of-pocket expenditure for people with MS was around $1300 annually throughout the projection period.

Conclusion: MS is associated with a significant economic burden on society, since it usually affects young adults during prime career- and family-building years. Canada has a particularly high prevalence of MS, so research such as the present study is essential to provide a better understanding of the current and future negative impacts of MS on the Canadian population, so that health care system policymakers can best plan how to meet the needs of patients who are affected by MS. These findings also suggest that identifying strategies to prevent MS and more effectively treat the disease are needed to mitigate these future impacts.

Highlights

- Multiple sclerosis (MS) is associated with a significant economic burden on society.
- The number of incident MS cases is expected to rise slightly in Canada from 4051 cases in 2011 to 4794 cases per 100 000 population in 2031.
- The MS prevalence for women aged 20 years and older is approximately 3 times higher than that for men.
- Most people affected by MS have an informal caregiver.
- Direct costs and indirect costs (e.g. out-of-pocket expenses) associated with MS are expected to increase over the next 20 years.

Keywords: multiple sclerosis, economic burden, Canada, microsimulation modelling, incidence, prevalence

Introduction

Multiple sclerosis (MS) is an unpredictable, chronic, inflammatory and degenerative disease of the central nervous system.[1-4] It is the most common non-traumatic disabling neurological condition among young

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adults in Canada.[5] Onset is typically between the ages of 20 and 40 years, and women are affected more often than men.[1,5] Although the etiology of MS remains unknown, genetic predisposition and environmental factors jointly trigger the disease.[2,6]

The prevalence of MS varies geographically, and high-prevalence areas include Canada, the northern United States, most of northern Europe, New Zealand, southeastern Australia and Israel.[7] The prevalence of MS in Canada is among the highest worldwide.[8] Because onset of MS occurs at a relatively early age, it affects individuals during their most productive years, and they face challenges in the workforce including underemployment, unemployment and long-term disability.[9-12] According to the MS Society of Canada's *Action on MS* report,[13] nearly 80% of Canadians with MS may find themselves unemployed. Determining the reasons for the high prevalence and lessening the burden of living with MS and other chronic neurological conditions have become major health policy concerns in Canada. Therefore, the Government of Canada initiated the National Population Health Study of Neurological Conditions (NPHSNC) to increase understanding of these conditions, with the long-term goal of reducing the burden of neurological conditions in Canada.[9]

Given the societal effects of MS, it is essential that comprehensive studies are undertaken to deal with the current impact and to plan for the future impact of the disease. We used Statistics Canada's Population Health Microsimulation Model (POHEM) framework, specifically the population-based, longitudinal, microsimulation model named POHEM-Neurological, to examine the health and economic impacts of the disease in Canada, including the expected incidence, prevalence, mortality and direct and indirect costs associated with MS over a 20-year time horizon from 2011 to 2031. The objective of this study is to provide key information to help shape strategies and public health policies on MS.

Methods

Population Health Model (POHEM)-Neurological

Statistics Canada's POHEM-Neurological framework is a population-based, longitudinal, microsimulation model[14] created as part of Canada's NPHSNC. The NPHSNC included 13 research projects and three national surveys aimed at examining multiple neurological conditions affecting Canadians.[9,14,15] The POHEM model was generated using MODGEN (Model Generator) software, version 11, a microsimulation programming language developed by Statistics Canada.[14] The model was developed to project the burden of select neurological conditions in Canada, including MS, from a societal perspective that includes health impacts and direct and indirect heath care costs by synthesizing the wide range of information from projects within the NPHSNC. POHEM is an empirically grounded model that uses Canadian demographic data and estimates of disease incidence and mortality rates to produce projections over the life cycle dynamics of Canadians.[16] The model's basic unit of analysis is individual people, or "actors," whose life course is modelled in continuous time using a Monte Carlo* approach. The dynamic simulation recreates the Canadian population at a given point in time (historically and in the future) and ages it, one actor at a time, until each actor's death.

Model characteristics

Caregivers, clinicians and individuals with policy expertise provided advisory input to the POHEM-Neurological model.[14] The project's advisors and research team created the model specification, including the purpose, structure and data sources. The main characteristics of the model were as follows:

- *Population-based*—reflecting the Canadian population, including important subpopulations designated by age, sex and region.
- *Open with respect to population*—allowing the population to change over time to reflect historical and projected births, deaths, immigration and emigration.
- *Coherent and consistent*—using a common definition of MS throughout the model and consistent in the approach used to model the epidemiology and costs related to the condition. Case ascertainment required that a clinician diagnose MS. A generic preference-based measure of health-related quality of life, the Health Utilities Index Mark 3 (HUI3; described later), was used to ascertain disease severity.[17]
- *High predictive accuracy*—able to generate accurate projections for the total Canadian population and for specific sex and age subgroups.
- *Useful for population health planning*—can be used to estimate future MS burden, including health care costs and caregiver burden.
- *Flexible and robust*—able to be developed further. Risk factors for the development of MS apart from age and sex were excluded from the current study. However, sociodemographic and health behaviour risk factors are part of other POHEM disease models and NPHSNC studies, and risk factors could be included in future MS modelling.[18]

Model development

Four steps made up the process of microsimulation model development: initialization, yearly updates, model validation and projection (Table 1). Only Canadian, population-based data sources were used for model initialization and yearly updates (data not shown; available from the authors upon request).

Initialization

Initialization began with historic birth cohorts from 1872, which we subjected to the observed historic death rate, similar to other Statistics Canada health models.[19,20] We added migration (immigration and emigration) to the birth cohorts, also reflecting historic observed or estimated events. The birth cohorts used observed data up to 2006; and projected births, deaths and migration following standard Canadian population projections (mid-growth scenario) as estimated by Statistics Canada for 2007 onward.

* The Monte Carlo method uses a broad class of computational statistical algorithms that rely on repeated random sampling to obtain numerical results. The essential idea behind the approach is the use of randomness to solve problems that might be deterministic in principle.

TABLE 1
Process for projecting multiple sclerosis prevalence, health burden and health care use in Canada using the POHEM-Neurological

Model generating step	Model activity	Details of the model step
Step 1: Generate an initial Canadian population	Initiated a predictive model by creating a synthetic cohort of Canadians.	Historic birth cohorts combined with annual deaths, immigration, and emigration. Observed demographic data to 2006 projected to 2031.[a]
Step 2: Update annual MS incidence and other model parameters	Each year to 2031, update population characteristics, MS incidence, health status and health care costs.	Each year, update synthetic cohort for demographic changes, MS incidence and deaths. For people with and without MS, estimate Health Utilities Index, health care use (formal and informal) and deaths.
Step 3: Validate and calibrate the model	Compare projected MS to observed prevalence in 2009.	Compare projected to observed MS prevalence, by age and sex. Calibrate the model if needed (no calibration undertaken for MS).
Step 4: Generate final projections from 2011–2031	Project MS incidence, prevalence, mortality, health utilities index and health care costs from 2011–2031.	Generate output tables from projections.

Abbreviations: MS, multiple sclerosis; POHEM, Population Health Model.

[a] See text for MS incidence, initialization, progression and mortality.

Yearly updates of actors' health profiles

An actor's health profile consists of six characteristics: (1) demographics (e.g. age, province of residence); (2) MS status; (3) health status; (4) presence of an informal caregiver; (5) health care costs; and (6) mortality (date of death). Each actor's health profile was updated throughout the year, either at the occurrence of an event (e.g. birthday, date of diagnosis of MS) or at the change of the calendar year, depending on the profile characteristic. All characteristics were calculated and modelled for people with and without MS[20] (data sources available from authors upon request).

Model implementation

Figure 1 shows life-course parameters used in the simulation model.

MS status: incidence

Since the model uses status quo assumptions to project the future impact, it assumes that MS incidence and risk and prognostic factors will remain stable throughout the projection period, consistent with findings in Nova Scotia[21] and Manitoba.[22] We generated prevalent MS actors in two steps. First, we applied empirical estimates of sex- and age-specific MS incidence rates to the model's synthetic Canadian population for each year, both historical and projected. We estimated incidence rates using a validated case definition algorithm[†] that had a sensitivity of 84.0% for adults aged 20 years and older,[23] and specificity of 99.9%[24] applied to a cohort from the province of Ontario. Individuals under age 20 years were excluded, given the low incidence of acquired demyelinating syndromes (ADS) leading to MS in Canadian children and adolescents. Incidence and prevalence rates estimated from the British Columbia (BC) population were of comparable magnitude to those of the published studies from Canadian settings and provincial/territorial pilots.[22,25]

Using these age- and sex-specific incidence rates, actors were classified as being diagnosed with MS, based on each actor's risk of developing MS at the beginning of each new calendar year. Incident MS cases accumulated over time to generate prevalent cases of MS.

Second, we applied MS-specific mortality risk to actors with MS. The MS mortality risk was a product of a mortality ratio for people with MS multiplied by the baseline mortality rate for the Canadian population within POHEM-Neurological. The general population mortality rate gradually decreases over time, reflecting the projected mortality (life expectancy) using birth cohorts and the Lee-Carter model as estimated by Statistics Canada.[26] This means that the projected mortality for people with MS decreased at the same rate as for Canadians living without MS, largely consistent with observations in British Columbia.[27] Using the BC administrative data prevalence cohort, we examined the number of deaths among individuals with MS, and compared it to the death rate among individuals without a neurological condition.

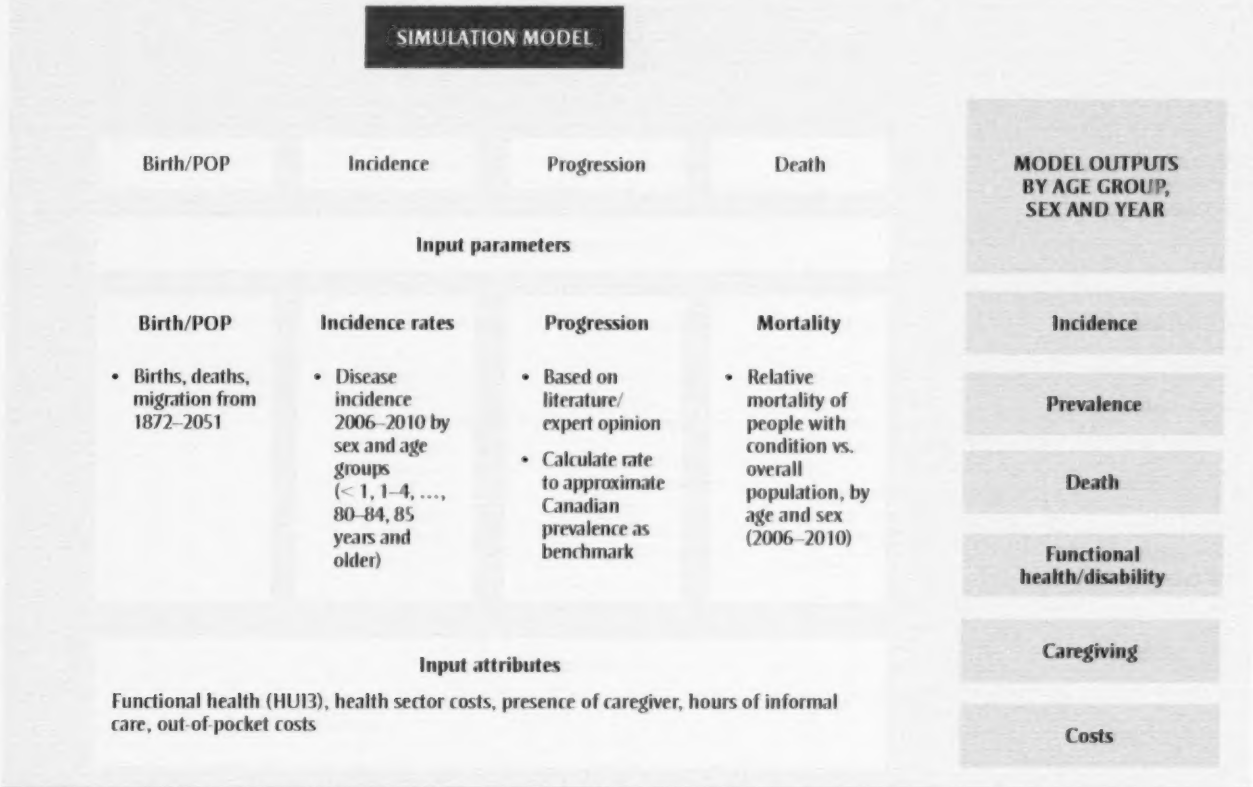
Health status

HUI3 is a utility-based measure that reflects health states ranging from perfect health (HUI3 = 1.0) through death (HUI3 = 0), including states considered to be worse than death (minimum HUI3 = −0.36), allowing for a range of severity levels.[17] The HUI3 assesses functional health across eight dimensions—cognition, emotion, mobility, dexterity, pain and discomfort, speech, vision and hearing—and was used based on the need for a common framework to assess functional health and disability due to MS. It validly measures and predicts functional health status and quality of life in people with MS.[17,28,29] Age-specific HUI3 means for people with MS were estimated from the 2011 Survey on Living with Neurological Conditions in Canada (SLNCC),[30] while HUI3 values for people without MS were derived from all cycles (1994 – 2010) of the National Population Health Survey (NPHS).[31]

The impact of MS can also be assessed by the years of life lost (YLL) due to the condition, that is, years lost due to premature death from a disease. To perform the YLL calculation, we first calculated the age of death for all actors with MS in each calendar year. Next, we estimated YLL for a scenario in which the mortality hazard for MS was the same as for actors without MS and recalculated the age of death: YLL was the

[†] The identification algorithm was 1 hospitalization or 5 physician visits in a 2-year period during which a diagnosis of MS was specified. An MS diagnosis was identified using the relevant International Classification of Disease (ICD) codes: (1) ICD-9(CM) 340; or (2) ICD-10(CA) G35.

FIGURE 1
Overview of the POHEM-Neurological model implementation


SIMULATION MODEL
Birth/POP
Incidence
Progression
Death
MODEL OUTPUTS BY AGE GROUP, SEX AND YEAR
Input parameters
Birth/POP
Incidence rates
Progression
Mortality
Incidence
• Births, deaths, migration from 1872–2051
• Disease incidence 2006–2010 by sex and age groups (< 1, 1–4, ..., 80–84, 85 years and older)
• Based on literature/ expert opinion
• Calculate rate to approximate Canadian prevalence as benchmark
• Relative mortality of people with condition vs. overall population, by age and sex (2006–2010)
Prevalence
Death
Functional health/disability
Caregiving
Costs
Input attributes
Functional health (HUI3), health sector costs, presence of caregiver, hours of informal care, out-of-pocket costs

Abbreviations: HUI3, Health Utilities Index Mark 3; POHEM, Population Health Model; POP, population.

difference in age of death between the two calculations. Health-adjusted life years lost (HYLL) indicates the years of life lost living in a healthy state, combining morbidity and mortality experience, and was estimated from the product of years of life lived (age of death) multiplied by the annual HUI3 for each actor over their lifetime.

Informal caregiving

Informal caregiving refers to unpaid caregiving provided by family and friends to Canadians living with a chronic health condition, disability or aging needs. For each actor in the model, we assessed informal caregiving at the end of every calendar year based on an actor's age, MS status and health status (HUI3). If an individual was assigned the presence of an informal caregiver, additional characteristics were also assigned based on empirical estimates from SLNCC and augmented with the 2012 General Social Survey (GSS)[32]: (1) hours of care received; (2) health status of their caregiver; and (3) out-of-pocket expenses incurred by caregivers.

Health care costs

Formal health care costs were estimated among incident and prevalent cohorts with MS, and were ascertained using administrative data in British Columbia and Ontario. We estimated the health care costs using 2010-dollar value; as such, inflation is not factored into the costs projections. In addition, prevalent and counterfactual cohort costs were obtained for the period 01 April, 2009, through 31 March, 2010, in both Ontario and BC. We examined incident cohort costs in Ontario over the same period. We obtained available incident cohort costs in BC for the 12-month period starting on 01 April of the incident year (2006, 2007 or 2008).

Formal health care costs were those covered by provincial health plans in health components grouped as follows: (1) acute hospitalization; (2) physician services; (3) prescription drugs data;[‡] (4) rehabilitation hospitals; (5) Ontario provincially funded home care; (6) Ontario residence and care in a long-term care facility; and (7) Ontario provincially funded assistive devices. Also, per capita out-of-pocket caregiver costs and informal care by caregivers (hours of care per week) were

[‡] BC had comprehensive prescription drug cost data for all prescriptions dispensed in community pharmacies, regardless of age, while Ontario had comprehensive data for persons aged 65 years and older with limited data for lower-income MS patients receiving provincial support for their disease-modifying therapies. Where we had costs from both provinces, these were weighted based on an input parameter (75% Ontario, 25% BC). The method used for this analysis was based on Wodchis WP, Bushmeneva K, Nikitovic M, McKillop I. Guidelines on person-level costing using administrative databases in Ontario. Working Paper Series. Vol 1. Toronto: Health System Performance Research Network; 2013. Available from: http://www.hsprn.ca/uploads/files/Guidelines_on_PersonLevel_Costing_May_2013.pdf

estimated from a national sample of caregivers from the 2012 GSS, whereas per capita out-of-pocket costs to individuals living with neurological conditions were estimated from a national sample through the SLNCC. Out-of-pocket expenses were those expenses not covered by private insurance or provincial health care plans, such as the cost of prescription and over-the-counter medications, assistive devices, rehabilitation therapy such as physical or occupational therapy and home care services. We estimated formal health costs separately for incident cases (within the first 12 months following incidence) or prevalent case (one year or more since incidence) of MS. As out-of-pocket costs are not captured in administrative databases, we used survey data to assess those expenses.

Comorbidity, counterfactual population and costs estimation

Individuals living with MS frequently have comorbid conditions.[33,34] Such conditions may be precursors to or related sequelae of MS, or may be present independent of MS. Individuals both with and without MS may experience some of these conditions. As such, it is sometimes difficult to isolate the contribution of MS to health care costs, caregiving or mortality, in the presence of comorbid conditions. To address this issue, we identified a counterfactual (nonneurological) population cohort to determine the net impact of MS. For example, if the prevalence of comorbidity X is greater among individuals with MS than without MS, then the additional health care costs (or receipt of caregiving hours) associated with this greater morbidity should be attributed to individuals living with MS. Conversely, if individuals with MS use less of a particular health care resource compared to individuals without a neurological condition, this lower utilization should also be reflected in our model.

The counterfactual nonneurological cohort consisted of all individuals in the respective datasets who had not otherwise been classified as having any of the seven neurological conditions of interest for the NPHSNC microsimulation project. In addition to MS, these conditions were Alzheimer's disease and other dementias, cerebral palsy, epilepsy, Parkinson's disease and parkinsonism, traumatic brain injuries and traumatic spinal cord injuries.

POHEM-Neurological validation

The model-projected prevalence of MS in 2010 was higher than that observed in the British Columbia data, and higher than that reported in some, but not all, Canadian provinces. Prevalence estimates across Canada are variable, with estimates per 100 000 population based on administrative data ranging from 207.3 in Ontario in 2010[34] to 266.9 in Nova Scotia in 2010,[21] and as high as 357.6 in the contiguous province of Alberta in 2004.[35] Despite this variance, the estimated age- and sex-specific prevalence rates are quite similar to estimates based on the 2010–11[36] Canadian Community Health Survey (CCHS; see Figure 2), recognizing that the CCHS did not capture those living in long-term care, who represent 5.8% to 9.2% of the MS population aged 65 years and older.[37] As such, we made no additional calibration to adjust POHEM-Neurological MS prevalence projections.

Projection

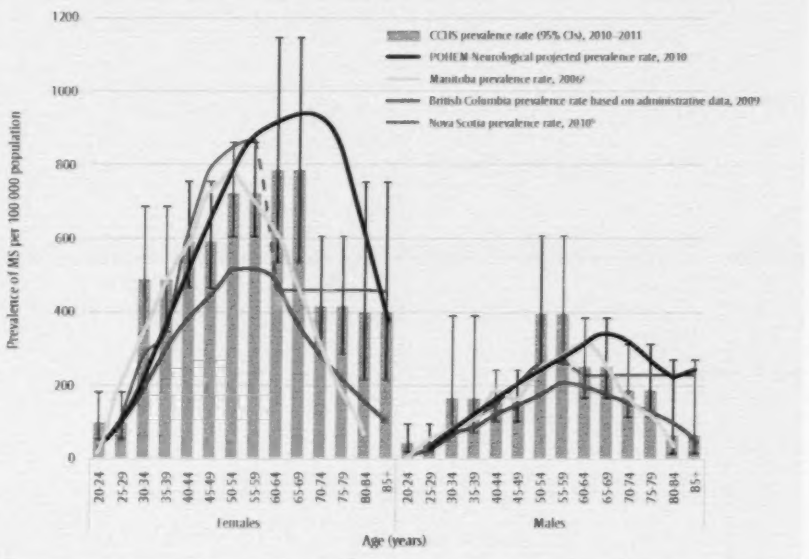
We projected 13 main model outputs through to 2031 including: (1) incident and prevalent MS cases in Canada; (2) YLL with MS; (3) HYLL; (4) health care costs, including costs for each of the seven sectors; (5) out-of-pocket expenses; and (6) hours of informal caregiving. In addition, we projected three parameters from the perspective of caregivers for MS: (1) hours of caregiving; (2) out-of-pocket expenses; and (3) health status (HUI3).

Results

The number of incident MS cases is expected to rise slightly from 4051 cases in 2011 to 4794 cases per 100 000 population in 2031 (data not shown). Among Canadians aged 20 years and older, MS prevalence is projected to rise gradually from 380 per 100 000 population in 2011 to 430 per 100 000 population in 2031, corresponding to 98 835 Canadians living with MS in 2011 and 133 635 Canadians living with MS in 2031 (Figure 3). The small increase in prevalence over the 20-year horizon reflects the assumption of stable MS incidence and mortality.

The MS prevalence for women aged 20 years and older is approximately 3 times higher than that for men (Figure 4). In

FIGURE 2
Prevalence rates of multiple sclerosis, by age and sex, projected from the POHEM-Neurological and estimates from other data sources, Canada, various dates

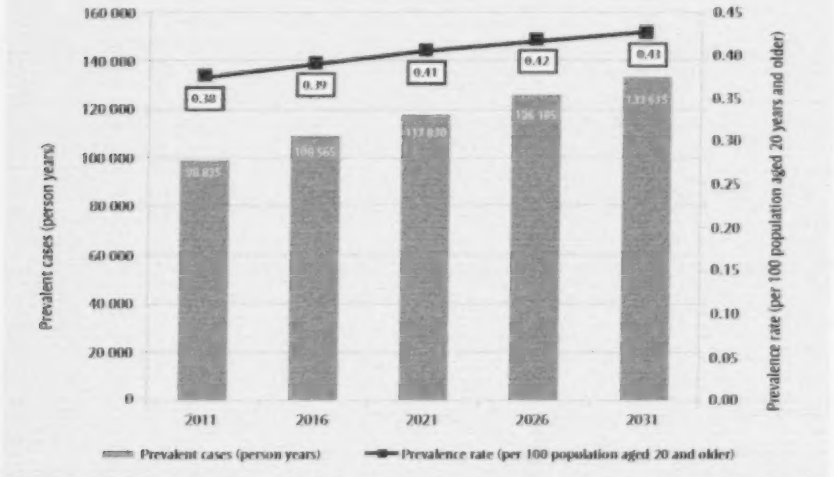


Abbreviations: CCHS, Canadian Community Health Survey; CI, confidence interval; MS, multiple sclerosis; POHEM, Population Health Model.

[a] From Marrie et al., 2010.[22]

[b] From Marrie et al., 2013.[21]

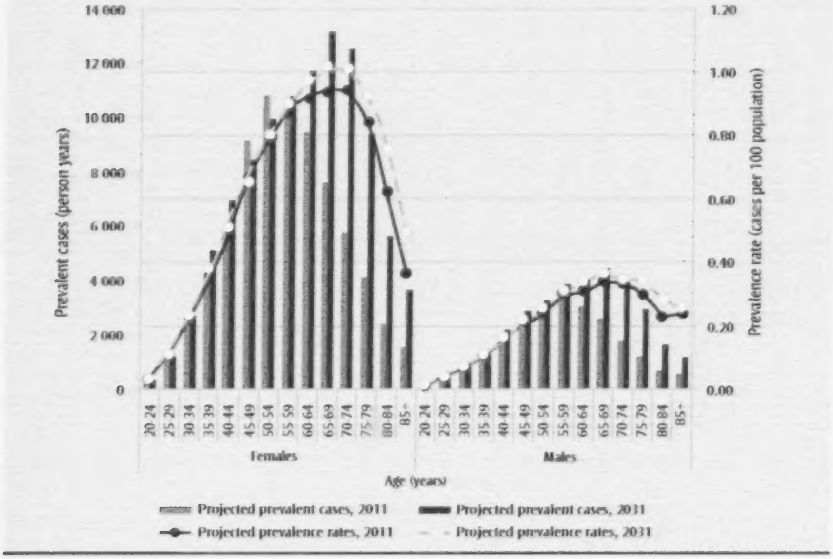
FIGURE 3
POHEM-Neurological projected multiple sclerosis prevalence count (person years) and rate, population aged 20 years and older, both sexes, Canada, 2011–2031



Abbreviation: POHEM, Population Health Model.

2011, the prevalence per 100 000 population was 580 for women compared to 200 for men. In 2031, the model projected a rate of 620 per 100 000 population for women compared to 220 per 100 000 for men. The prevalence of MS increases dramatically for both sexes from ages 20 to 24 years until the age group 60 to 69, after which the prevalence begins to decline, reflecting the fact that incidence is highest for individuals in their late thirties through their early sixties.

FIGURE 4
POHEM-Neurological projected multiple sclerosis prevalence count (person years) and rate, by age and sex, Canada, 2011 and 2031



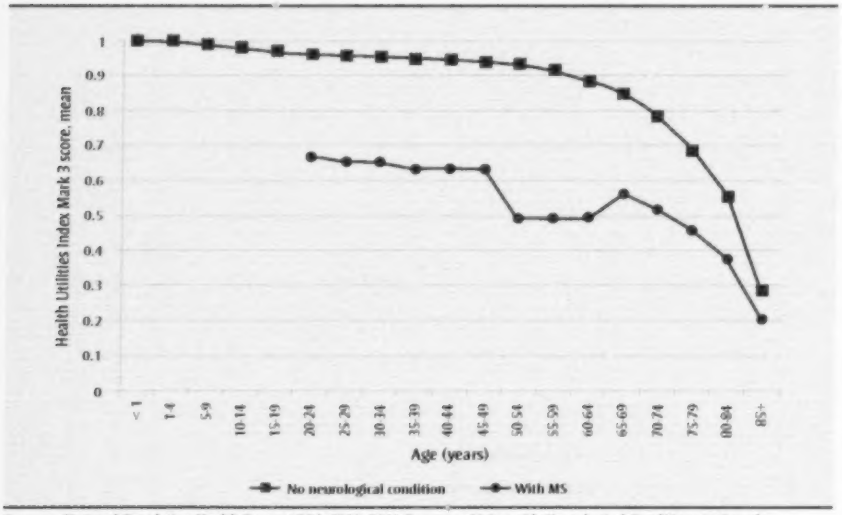
Abbreviation: POHEM, Population Health Model.

Regarding functional health and disability due to MS, the SLNCC showed that people of both sexes with MS have lower HUI3 scores compared to people with no neurological condition (Figure 5). Although HUI3 scores declined with age in both populations, on average, the HUI3 declined 15 years earlier in the MS population, and the gap in HUI3 scores persisted across all age groups. These trends were projected to remain the same throughout the projection period, as the model assumes no change in age-specific HUI3 (for those with MS or with no neurological condition).

Although people with MS born in more recent decades can expect to live longer than those born in earlier decades, they will not live as long as those without MS. Women with MS born between 2010 and 2019 will live five fewer years than women without MS, while men with MS born in the same decade will live four fewer years than men without MS. People living with MS will experience longer periods of living in poor health relative to their counterparts who do not have MS (Table 2). For instance, females diagnosed with MS born between 2010 and 2019 are projected to lose an average of 19.8 years in full health compared to 12.4 years for their counterparts who do not have MS. Similarly, males with MS born in the same decade are projected to lose 17.2 years in full health compared to 10.7 years for those who have not been diagnosed with MS.

Table 3 provides a snapshot of the observed 2011 per capita health care costs for Canadians with MS and those without MS. At all ages, the mean total health care costs were substantially higher for those with MS than without MS. For instance, in the 20 to 24 age group, the projected total health care costs are about 13 times higher for those with MS than for those without MS. The health care costs attributed to living with MS remain consistently 5- to 10-fold higher from ages 25 to 64 years, then drop to four times higher and remain stable for the rest of the age categories. When health care costs are subdivided, physician, hospital and prescription drug costs are consistently higher in the MS population than in the non-MS population (Table 3). However, the disparity between populations is greatest for drug costs, which are over 40-fold higher in the MS population aged 20 to 24 years than in the non-MS population.

FIGURE 5
Average Health Utilities Index Mark 3 score, population with multiple sclerosis and those with no neurological condition, by age, both sexes, Canada



Sources: National Population Health Survey 1994–2010; 2011 Survey on Living with Neurological Conditions in Canada.
Abbreviation: MS, multiple sclerosis.

The additional expenditures incurred by Canadians aged 20 years and older with MS are about three to eight times higher in the three main components (physician, hospital and drugs) than the expenditures incurred in the absence of seven major neurological conditions mentioned above. The additional costs incurred by those with MS are consistently higher among people aged 25 to 49 years but thereafter begin to stabilize and then decrease (Table 4). By age 70 years, the gap between the base and additional expenditures decreases to three-fold and remains at that level for the age groups 70 years and above, likely reflecting accrual of morbidity in the general population.

The total projected health care sector costs show that the additional expenditures due to MS are about four times higher than the base expenditures associated with the condition. As well, these costs are projected to increase over the projection period. Additional expenditures incurred for drugs for the population with MS are about 10 to 20 times higher than for Canadians living without any of the seven major neurological conditions noted earlier. The trend is prominent between the ages of 20 and 49 years and persists throughout the 20-year projection period.

The total out-of-pocket expenses incurred by Canadians with MS are projected to increase from $126 million in 2011 to $170 million in 2031 (Table 5). Out-of-pocket costs start to rise around age 25 until age 54 years, when the costs begin to stabilize, and then begin to decrease after age 65 years; the decrease in the per capita cost may be partly due to mortality. The average out-of-pocket expenditure for people with MS is around $1300 annually throughout the projection period.

The utilization of informal caregiving also reflects an additional burden on family and others associated with people living with MS. Based on 2011 data the proportion of Canadians receiving informal care is higher among those with MS than those with no neurological conditions across all age groups. It is estimated that 34% of those aged 20 to 24 years with MS have an informal caregiver, rising to 59% for those with MS aged 60 to 64 years (see Figure 6). In general, the burden for informal caregiving on people with MS emerges earlier and remains high throughout their lifetime.

TABLE 2
POHEM-Neurological mean years lived and health-adjusted life years, individuals with and without multiple sclerosis, by sex and decade of birth, Canada, 1970–2019

Decade of birth	Individuals with MS (YL)	Individuals without MS (YL)	HALY for individuals with MS	HALY for individuals without MS
Female				
1970–1979	81.7	86.0	62.7	74.0
1980–1989	82.5	86.9	63.0	74.7
1990–1999	82.7	87.4	63.1	75.0
2000–2009	82.9	87.6	63.2	75.2
2010–2019	83.0	87.7	63.2	75.3
Male				
1970–1979	80.6	81.5	63.8	71.3
1980–1989	81.0	82.8	63.8	72.3
1990–1999	81.6	83.4	64.3	72.8
2000–2009	81.4	83.8	63.9	73.1
2010–2019	81.3	84.0	64.1	73.3

Abbreviations: HALY, health-adjusted life years; MS, multiple sclerosis; POHEM, Population Health Model; YL, years lived.

Discussion

We used the POHEM-Neurological microsimulation model with status quo assumptions to project the changing nature of MS in Canada with respect to the incidence of new cases, rising prevalence and future burden, in terms of costs and impact on health over the next 20 years. By 2031, the prevalence of MS will exceed 400 persons per 100 000, corresponding to more than 133 000 affected Canadians, and a 13% change from 2011. After accounting for additional expenditures due to MS, total health sector costs for MS are expected to reach $2 billion by 2031. Further, 65% of people living with MS are projected to need informal care by 2031.

We found that people living with MS have a reduced life expectancy, and have longer

TABLE 3
Estimated mean per capita costs for population with MS compared to those without MS, by major cost components and age group, Canada, 2011

Age group	With MS ($)				Without MS ($)				Ratio of MS to non-MS cost by age group			
	Health care sector[a]	Physician	Hospital	Prescription drugs	Health care sector[a]	Physician	Hospital	Prescription drugs	Health care sector[a]	Physician	Hospital	Prescription drugs
20–24	11 158	1718	1400	7439	854	326	340	170	13:1	5:1	4:1	44:1
25–29	10 845	1351	1249	7488	1066	411	420	216	10:1	3:1	3:1	35:1
30–34	10 816	1275	2010	6760	1215	469	456	266	9:1	3:1	4:1	25:1
35–39	11 011	1126	1928	6764	1216	457	414	315	9:1	2:1	5:1	21:1
40–44	12 104	1217	2780	6145	1305	472	422	372	9:1	3:1	7:1	17:1
45–49	13 375	1314	3247	5654	1575	538	513	468	8:1	2:1	6:1	12:1
50–54	14 067	1313	3816	4927	1998	644	676	592	7:1	2:1	6:1	8:1
55–59	15 947	1436	5111	4024	2514	754	882	750	6:1	2:1	6:1	5:1
60–64	16 550	1532	4973	3543	3205	898	1201	917	5:1	2:1	4:1	4:1
65–69	18 523	1607	6146	2542	4130	1096	1634	1123	4:1	1:1	4:1	2:1
70–74	22 218	1906	6032	2447	5169	1270	2115	1350	4:1	1:1	3:1	2:1
75–79	27 131	1964	8721	2433	6344	1444	2686	1521	4:1	1:1	3:1	2:1
80–84	30 833	2153	7705	2666	7547	1502	3238	1603	4:1	1:1	2:1	2:1
85+	32 310	2079	6906	2042	9196	1354	3711	1417	4:1	2:1	2:1	1:1

Abbreviation: MS, multiple sclerosis.

[a] Total health care sector costs, including physician, hospital, drugs, rehabilitation, long-term care, home care and assistive devices.

periods of living with a poorer health-related quality of life (as reflected by lower scores on the HUI3), which limits their ability to participate in activities of daily living. Other studies have also shown that the MS population has lower quality of life than the general population.[38] The HUI3 is strongly associated with physician-scored measures of disability,[39] which tend to worsen with older age,[40] consistent with our findings. Temporal trends in these associations have not been evaluated; thus, an assumption of stability in these trends across time was reasonable. As MS typically presents in young adults between the ages of 18 and 40 years, early disability and premature death mean that affected individuals have a reduced potential to contribute to economic activities.

Consistent with the existing literature, model outputs indicate that per capita health care expenditures are higher for individuals with MS[41] than those in the non-MS population. Although the rate of hospitalization has declined in the MS population over time, rates remain higher than in an age- and sex-matched population without MS.[42] Other health care services are also used more heavily by the MS population than the general population.[38] Prescription drug expenditures are particularly high, likely reflecting the very high costs of disease-modifying therapies for MS.[43] We observed that among those aged 20 to 34 years, the group most likely to be using disease-modifying therapies, prescription drug expenditures constituted 62.5% to 69% of total health care expenditures. In a survey of 1909 Americans with MS in 2006, disease-modifying therapies constituted the single biggest MS-related cost,[44] and in a US-based study that used administrative data, pharmacy expenditures constituted 65% of total MS-related health care costs in 2004.[45]

Although the microsimulation model projected only a slight increase in the prevalence of MS over the next 20 years, the burden of MS on affected individuals, the health system and society is projected to increase substantially. This increase reflects the improving life expectancy for people MS, with long periods lived in poor health and with functional disability. Formal health care costs will increase, and persons with MS will incur substantial out-of-pocket costs, which are expected to increase over the 20-year horizon. The demand for informal caregiving will also increase, further affecting the health and economic well-being of informal caregivers.[46-48]

Strengths and limitations

Our study projections fill gaps in current pan-Canadian population-based estimates, and are also consistent with the existing Canadian literature.

POHEM-Neurological used status quo assumptions related to incidence, relative mortality and functional health. With the exception of risks associated with age and sex, Canada's population growth, migration patterns and aging patterns are assumed to remain the same over the

TABLE 4
POHEM-Neurological projected total health care costs[a] for individuals with MS, divided into base and additional components to total expenditure, by age group and projection year, Canada

Age group	2011		2016		2021		2026		2031	
	Base	Additional	Base	Additional	Base	Additional	Base	Additional	Base	Additional
	Total costs ($ millions)									
20–24	0.4	4.2	0.3	3.9	0.3	3.6	0.3	4.0	0.4	4.2
25–29	1.7	15.7	1.8	16.0	1.8	16.8	1.7	15.3	1.7	15.3
30–34	3.9	30.8	4.3	33.6	4.5	34.9	4.6	35.5	4.3	33.4
35–39	6.4	51.7	6.8	54.2	7.2	57.5	7.7	61.0	7.9	62.5
40–44	10.2	84.5	10.1	84.2	10.5	86.8	11.2	92.7	11.9	97.8
45–49	18.7	139.7	16.2	122.4	16.1	122.2	16.7	126.1	17.7	133.6
50–54	27.8	168.2	28.3	171.1	24.9	150.5	25.1	152.0	26.2	159.1
55–59	35.5	189.6	40.2	214.2	41.1	219.5	36.3	194.0	36.6	196.3
60–64	40.1	166.9	48.3	201.8	54.5	227.0	55.8	232.7	50.2	209.4
65–69	41.9	145.9	50.9	176.7	61.9	216.1	70.3	244.8	72.3	251.6
70–74	39.0	128.8	49.7	164.1	60.6	200.2	73.5	241.9	84.7	279.1
75–79	33.6	110.1	39.9	130.8	52.0	170.2	63.9	209.0	78.0	254.5
80–84	23.1	71.2	27.3	83.5	32.9	100.5	43.7	134.3	54.3	166.4
85+	18.9	47.6	21.6	54.8	26.1	66.0	32.7	82.8	43.2	109.5
Total	301.2	1355.0	345.6	1511.2	394.4	1671.7	443.4	1826.1	489.4	1972.8

Abbreviations: MS, multiple sclerosis; POHEM, Population Health Model.

Note: Base costs are those equal to the mean per capita costs among individuals without neurological conditions, if applied to individuals with MS. Additional costs represent the difference in costs for individuals with MS compared to base costs.

[a] Total health care sector costs include physician, hospital, drugs, rehabilitation, long-term care, home care and assistive devices.

20-year projection time horizon. Other risk factors were not considered because it was unclear which risk factors were most salient, and because they were likely to vary over the projection period. The future trend in terms of a cure for MS is assumed to remain unchanged over the projection period, although advances in health care could provide alternative ways to prevent, diagnose or treat MS. POHEM-Neurological presumes that incident cases of MS begin to occur at age 20, but up to 5% of individuals have symptom onset under age 16 years,[49] although some of these individuals will not be diagnosed until adulthood. The effects of this assumption are likely to be small, given that most MS cases are diagnosed at age 20 years and older. The model shows peak incidence occurring at a later age than other Canadian studies undertaken in Nova Scotia[21] and Manitoba;[22] however, the overall incidence rates produced by the model were similar to these earlier studies.

Other limitations should be considered. The model projected a conservative increase in the prevalence of MS of 6.5% per decade. In all Canadian provinces where it has been evaluated over time, the prevalence of MS has increased,[21-24,36] consistent with our findings. However, the degree of change has varied, from 13.5% per decade in Manitoba[22] to 55% per decade in Ontario.[24] That variance could be a reflection of the application of diagnostic or reporting criteria, or, our findings may underestimate the future impact of MS.

Our findings also assume that there will be no major treatment advances that can improve function or reduce mortality, and that the general patterns of health services utilization will persist in the future (i.e. status quo assumptions). Future iterations of the POHEM-Neurological could address the limitations posed by such assumptions by incorporating additional primary research on risk- and prognosis-factor dynamics in MS.

Microsimulation itself has certain limitations, including susceptibility to the quality of data used as input parameters, and the ability to model and quantify uncertainty of projections.[50] With respect to input data quality, while attempts are made to ensure that the most appropriate data are used in the model, newer data that are more accurate will become available in the future. Such information can be updated in a microsimulation model in the future, and the impact of such changes can be assessed. Regarding the projection uncertainty, methodologies intended to improve projection accuracy are currently under development that could be applied in future scenario projections.[51,52]

Conclusion

POHEM-Neurological has shed light on the escalating costs of MS and its social, economic and health impacts. People living with MS face progressive physical and cognitive impairment and reduced quality of life. A key policy issue is the cost of MS

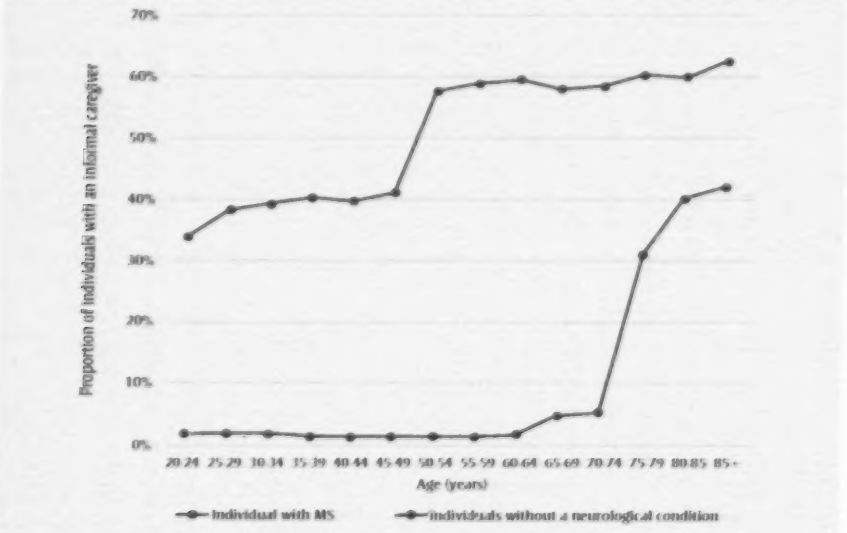
TABLE 5
Projected total out-of-pocket costs[a] for individuals with multiple sclerosis, by age group and projection year, Canada, 2011–2031

Age group	2011	2016	2021	2026	2031
	Total costs ($ millions)				
20–24	0.5	0.4	0.4	0.5	0.5
25–29	1.8	1.9	2.0	1.7	1.8
30–34	3.6	4.0	4.1	4.3	3.9
35–39	6.7	7.1	7.5	7.9	8.2
40–44	9.9	10.0	10.2	11.0	11.5
45–49	15.1	13.1	13.1	13.5	14.3
50–54	17.8	18.1	15.9	16.1	16.8
55–59	17.9	20.5	20.8	18.4	18.7
60–64	16.0	19.2	21.7	22.3	20.0
65–69	13.1	15.8	19.2	21.8	22.3
70–74	9.6	12.3	15.1	18.2	20.9
75–79	6.8	8.1	10.4	12.8	15.7
80–84	4.0	4.7	5.7	7.5	9.3
85+	2.8	3.2	3.8	4.8	6.4
Total	125.7	138.2	149.9	160.7	170.4

[a] Out-of-pocket expenses include costs incurred by a patient that are not reimbursed by provincial health plans.

and how best to mitigate the cost to society, as health care costs are projected to persistently increase, particularly for prescription drugs. Future microsimulation studies can be tailored to provide the evidence needed by policy makers to support the allocation of limited health care dollars. For instance, POHEM-Neurological could provide evidence to support cost-benefit analyses of various policy recommendations aimed at reducing the societal impacts of the condition.

FIGURE 6
POHEM-Neurological projected proportion of individuals with an informal caregiver, individuals with MS and those without a neurological condition, by age group, Canada, 2011



Source: POHEM-Neurological.
Abbreviations: MS, multiple sclerosis; POHEM, Population Health Model.

Acknowledgements

This study was supported by the Institute for Clinical Evaluative Sciences (ICES), which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care (MOHLTC). The opinions, results and conclusions reported in this paper are those of the authors and are independent from the funding sources. No endorsement by ICES or the Ontario MOHLTC is intended or should be inferred.

Parts of this material are based on data and information compiled and provided by CIHI. However, the analyses, conclusions, opinions and statements expressed herein are those of the authors, and not necessarily those of CIHI.

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Conflicts of interest

The authors disclose no conflict of interest.

Authors' contributions

NA, RM, CB and RG contributed to the paper concept, drafting, analysis interpretation and critical review of the article. RM provided specialised content expertise on MS, while CB, RG, DGM, RW, PF, JB, KT and KR contributed to data acquisition, microsimulation modelling and review of the article.

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The cost of diabetes in Canada over 10 years: applying attributable health care costs to a diabetes incidence prediction model

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Abstract

Introduction: Our objective was to estimate the future direct health care costs due to diabetes for a 10-year period in Canada using national survey data, a validated diabetes risk prediction tool and individual-level attributable cost estimates.

Methods: We used the Diabetes Population Risk Tool to predict the number of new diabetes cases in those aged 20 years and above over a 10-year period (to 2022), using 2011 and 2012 Canadian Community Health Survey data. We derived attributable costs due to diabetes from a propensity-matched case control study using the Ontario Diabetes Database and other administrative data. We calculated total costs by applying the respective attributable costs to the incident cases, accounting for sex, year of diagnosis and annual disease-specific mortality rates.

Results: The predicted 10-year risk of developing diabetes for the Canadian population in 2011/12 was 9.98%, corresponding to 2.16 million new cases. Total health care costs attributable to diabetes during this period were $7.55 billion for females and $7.81 billion for males ($15.36 billion total). Acute hospitalizations accounted for the greatest proportion of costs (43.2%). A population intervention resulting in 5% body weight loss would save $2.03 billion in health care costs. A 30% risk-reduction intervention aimed at individuals with the highest diabetes risk (i.e. the top 10% of the highest-risk group) would save $1.48 billion.

Conclusion: Diabetes represents a heavy health care cost burden in Canada through to the year 2022. Our future cost calculation method can provide decision makers and planners with an accessible and transparent tool to predict future expenditures attributable to the disease and the corresponding cost savings associated with interventions.

Keywords: diabetes, economics, attributable cost, prediction model, incidence, Canada

Highlights

- We created an accessible and transparent tool to help health decision makers calculate future diabetes costs.
- We predicted the number of new diabetes cases in Canada in those aged 20 years and above over the next 10 years (2011/12 to 2021/22) and linked this with actual individual-level health care costs of diabetes.
- By 2022, 2.16 million new cases of diabetes are expected, corresponding to $15.36 billion in health care costs related to diabetes.
- This tool can model various risk-reduction interventions in the population; e.g. a 5% weight loss in the population would save $2.03 billion and a 30% risk reduction in the group with the highest diabetes risk would save $1.48 billion.

Introduction

The management and prevention of diabetes remains a health priority in Canada. With approximately 1.96 million people living with diabetes,[1] and with a growing number expected to develop the chronic condition in the future, considering wide-scale strategies to curb the disease is of great importance. In particular, diabetes presents a significant constraint on the Canadian health care system. In 2008, it was estimated that the cost of hospital care, physician care and drugs for diabetes was $2.18 billion.[2] Looking toward the future, the Canadian Diabetes Association has projected that the overall direct cost of diabetes will be $3.1 billion in 2020, based on 3.7 million prevalent cases predicted using a specially developed diabetes cost model.[3] At the individual level, Goeree and colleagues have estimated that the attributable cost per incident case of diabetes in Ontario is approximately $2930 in the first year after diagnosis and $1240 in following years.[4] Recently, Rosella and colleagues expanded upon this work to include a greater number of direct costs in the province, and found that the mean attributable cost during eight years of follow-up was $9731 for females and $10 315 for males.[5]

While work has been done across Canada to estimate the future economic costs of diabetes,[3,6] most cost estimates and models are complex, not transparent or not readily usable by health decision makers. With the goal of preventing diabetes, a tool that allows decision makers to

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estimate the economic impact of future incident diabetes cases on the health care system would allow for more effective planning. From a program perspective, being able to quantify how actions today may shape case development and associated health care spending in the future is a considerable advantage in evaluating strategies. The objective of this study is, first, to estimate the future 10-year direct health care costs due to new diabetes cases in Canada using national survey data and individual-level attributable costs within the context of a diabetes risk prediction tool; and second, to apply the tool to two hypothetical intervention scenarios aimed at decreasing diabetes incidence in the population.

Methods

Diabetes risk and incidence

To estimate the predicted risk and number of new diabetes cases within the next 10 years, we used the Diabetes Population Risk Tool version 2.0. DPoRT 2.0 is an updated iteration of DPoRT, a predictive algorithm developed to calculate future population risk and incidence of physician-diagnosed diabetes in those aged 20 years and over. DPoRT was derived using national survey data individually linked to a chart-validated diabetes registry. This cohort was then used to create sex-specific survival models using baseline risk factors from the survey for diabetes incidence. Specifically, we assessed the probability of physician-diagnosed diabetes from the interview date until censoring for death or end of follow-up. The model was developed in the Ontario cohort and predictions from the model were validated against actual observed diabetes incidence in two external cohorts in Ontario and Manitoba. Variables used within its two sex-specific models include a combination of hypertension, ethnicity, education, immigrant status, body mass index, smoking status, heart disease and income. Full details on the model specification and validation can be found elsewhere.[7] The regression model can run on nationally available population health surveys and has been updated (DPoRT 2.0) and used to established prevention targets for diabetes.[8]

For this study, we used DPoRT 2.0 to generate incidence predictions based on the recent 2011 and 2012 Canadian Community Health Survey (CCHS). The CCHS collects information on the demographics, health status and determinants of health of the Canadian population. It is a nationally representative survey that uses a cross-sectional study design and is administered on an ongoing basis, with annual data reporting. It covers 98% of the population aged 12 years and older; exceptions include people living on Indian reserves and Crown lands, institutionalized residents, full-time members of the Canadian Forces and people living in particular remote regions.[9] The sample size for this survey was 124 929; after applying exclusion factors (e.g. respondents aged under 20 years and those with existing diabetes were excluded), the final sample size used in analyses for this study was 90 631, representing 21 598 180 people when weighted.

Intervention scenarios

In addition to baseline estimates (i.e. all demographic and risk factors as outlined above), we ran two hypothetical intervention scenarios to examine how implementing interventions aimed at reducing diabetes risk would affect the incidence of the disease and the cost to the health care system.

First, we modelled a nontargeted intervention leading to an average 5% weight loss in the population. A 5% drop in weight has a positive impact on glycemic and cardiovascular health clinically[10] and represents a modest and realistic weight decrease for many. This intervention would reflect a large-scale change, such as a change in the built environment (e.g. it has been shown that populations in highly walkable areas have lower overweight and obesity prevalence rates[11]) or the implementation of improved nutrition labelling.

Second, we ran an intervention scenario in which those in the highest-risk decile (i.e. those who have a 10-year risk of developing diabetes $\geq$ 22.6%) were targeted for an intervention leading to a 30% reduction in their risk. For example, this approach might consist of a targeted lifestyle intervention program or a pharmaceutical intervention that has proven efficacy in randomized trials.[12]

Attributable cost estimates

To estimate future costs attributed to diabetes, we used results from a recent propensity-matched cohort study.[5] Briefly, this study used the Ontario Diabetes Database (ODD) to identify new cases of physician-diagnosed diabetes from 01 April, 2004, to 31 March, 2012. Three control subjects without diabetes were matched to each person with diabetes; they were hard matched on index date ($\pm$ 30 days), age ($\pm$ 90 days) and the logit of the propensity score. This score was the predicted probability of developing or not developing diabetes, calculated from a logistic regression consisting of age, rurality, comorbidity, geographic location and neighbourhood income quintile as predictive variables.

During this eight-year follow-up period, individual-level direct health care costs were tracked annually. These costs were extracted by linking various health care utilization databases and following a person-level costing methodology specifically developed and validated for Ontario administrative databases.[13] These costs were from the perspective of the health care system, and included costs from inpatient hospitalizations, emergency department visits (ED), same-day surgeries (SDS), dialysis, oncology clinic visits, fee-for-service physician and non-physician services, non-fee-for-service physicians, prescription medications, laboratory, rehabilitation, complex continuing care, long-term care, mental health inpatient stays, home care services and medical devices. Attributable costs were calculated as the difference in cost between those with and without diabetes.

Cost calculations

We developed a cost calculator to use DPoRT 2.0 incidence predictions and per-patient attributable cost values to estimate the direct health care costs attributable to diabetes, over a future 10-year period. All calculations were sex-specific, reflecting differences in health care use[5] and perhaps self-care patterns.[14] The number of incident cases projected to occur each year was multiplied by the corresponding per-patient annual cost, dependent on the time since the diabetes diagnosis, and taking into account annual mortality rates, which were generated from the age-specific mortality rates of patients in the ODD. Mortality rates were specific to year of follow-up. We assumed that deaths occurred halfway through the year, and as such, half of those who died contributed costs to that specific year. Because the individual costing estimates used eight years of follow-up in the analysis, it was assumed that the costs attributable to

individuals who contributed costs in years 9 and 10 after diagnosis did so at the same monetary value as year 8. As there was a downward tendency in health care costs observed for the first eight years, we conducted a sensitivity analysis whereby years 9 and 10 costs were estimated by following a linear trend to see the effect of changing the individual attributable costs on the resulting cost estimates.

Cost distribution by sector

In order to estimate the burden of costs by sector, the mean costs per health care segment over the eight years of follow-up were converted to percentages and multiplied by the total costs estimated from the cost calculator.

We performed all statistical analyses using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

The predicted 10-year risk of developing diabetes for the Canadian population as a whole is 9.98%, corresponding to 2 156 000 new cases between 2011/12 and 2021/22. The risk is higher among males than females (11.23% vs. 8.85%), with males representing more new cases overall. The estimated total health care cost of these new cases is $15.36 billion.

If a population-level (small impact and large reach) intervention was put in place that resulted in an average body weight loss of 5% in the population, the 10-year predicted risk of developing diabetes would drop to 8.67%, resulting in 1 873 000 cases developing in this time period (Table 1). This reduced number of new cases would cost $13.33 billion, resulting in a savings of $2.03 billion when compared with baseline characteristics.

In contrast, if an intervention targeting those with the highest predicted risk (the top 10% of the highest-risk group) in the population were carried out, the overall risk of developing diabetes would be 9.02%. This would translate to 1 949 000 new cases, at a total cost of $13.88 billion (Table 1). Compared with the baseline scenario, $1.48 billion in direct health care costs would be averted.

When we estimated costs for years 9 and 10 using a linear trend based upon years 1 to 8 of observation, the results were not very different from estimates assuming equal costs for years 8, 9 and 10. Because the total difference was approximately $15.96 million, we determined that using the originally proposed costing methodology was appropriate.

TABLE 1
Health care costs attributable to diabetes, baseline scenario and two hypothetical intervention scenarios, Canada, both sexes, 2011/12 to 2021/22

		10-year risk[a] (%)	Incidence (# of cases, thousands)	10-year overall cost ($, billions)
Baseline characteristics				
Overall		9.98	2156	15.36
Sex	Female	8.85	1000	7.55
	Male	11.23	1156	7.81
5% weight loss in population				
Overall		8.67	1873	13.33
Sex	Female	7.79	880	6.64
	Male	9.64	993	6.70
30% risk reduction in highest-risk group[b]				
Overall		9.02	1949	13.88
Sex	Female	8.20	927	6.97
	Male	9.93	1022	6.91

Abbreviation: $, Canadian dollars.
[a] 10-year risk of developing diabetes.
[b] The highest-risk group has a 10-year risk of developing diabetes ≥ 22.6%.

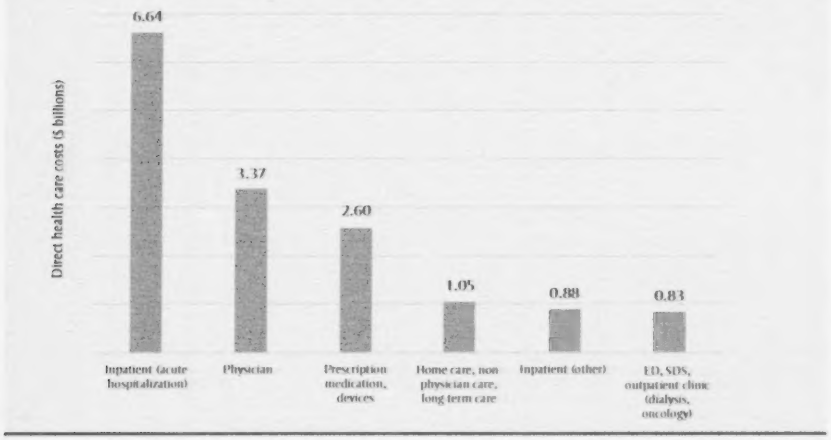
In terms of distribution of costs, the largest proportion of health care spending goes to acute hospitalizations: approximately 43.2% ($6.64 billion). The second largest share is for physician costs, which represent 21.9% ($3.37 billion) of all costs. Prescription medications and assistive devices account for 16.9% of costs ($2.60 billion); followed by home care, nonphysician care and long-term care ($1.05 billion); other inpatient services ($0.88 billion); and ED, SDS and outpatient clinic services ($0.83 billion) (Figure 1).

Discussion

Between 2011/12 and 2021/22, new cases of diabetes are estimated to result in $15.36 billion in Canadian health care costs, almost two-thirds of which will be spent on acute hospitalizations and physician services (65.1%). This study introduces a novel way of estimating future health care costs attributable to new cases of diabetes. The linkage of an incidence prediction model with individual-level attributable costs allows for estimates to be derived for different segments of the population, including sex-specific estimates, as well as region-specific costs. The ability to predict incident cases annually also allows users to calculate costs per year in the future and costs by year of follow-up for any number of years ranging from one to 10.

Because this is a new cost methodology that focusses on the development of incident diabetes cases, it is difficult to compare these estimates with previously projected costs. Previous Canadian estimates have used varying health care costs associated with diabetes, and have either focussed on projected costs per year based on prevalent cases[3,6] or have retrospectively reported on cases that have already occurred.[15-17] The report *Economic Burden of Illness in Canada, 2005 – 2008* (EBIC) offers comprehensive cost estimates for a variety of conditions, including diabetes.[2] Our cost methodology differs from that used in EBIC in that EBIC used prevalence-based costs while we used incidence-based costs. In addition, we estimated attributable costs; our costs represent the difference in health care costs that are directly attributable to diabetes, while EBIC only generates overall cost of illness. This is achieved by using a propensity-matched cohort design.[5] Finally, EBIC did not couple these estimates with predictions on future cases and therefore did not

FIGURE 1
Distribution of total 10-year direct health care costs attributable to diabetes ($ billions), Canada, 2011/12 to 2021/22



Abbreviations: ED, emergency department visits; SDS, same-day surgery.
Note: Figures have been rounded.

allow for intervention planning or estimates on future cost burden.

Strengths and limitations

This methodology has unique strengths. First, the costs are based on actual observed health care cost data from a prospective cohort over eight years of observation. Therefore, these are not projected estimates only, but instead reflect the reality of contemporary diabetes costs to the health care system. The use of attributable cost as a metric is also advantageous as it represents the excess cost of disease beyond average spending, due to the comparison with the group without the disease. Using total costs based only on the diseased population can overestimate the spending on disease and can provide inflated evaluations.[3]

Second, this method is simple to apply and can be used by a variety of end users. This is the aim of the tool itself—to be accessible and transparent for use within applied settings, such as provincial ministries of health and regional health bodies. Being able to model intervention scenarios, unique to the user's program goals and region, is an added benefit for health planners and decision makers who seek to estimate the economic offsets of various diabetes prevention strategies. Being able to estimate the cost averted, in addition to the number of cases prevented through customized intervention strategies, allows for the evaluation of different policy options and can assist in determining how best to move forward with chronic disease prevention activities. For example, in Canada, there are dozens of promising policy choices and interventions aimed at healthy living being led through federal, provincial and regional partnerships.[18] Such programs could benefit from a tool that would factor in context-specific population characteristics to evaluate the most appropriate and feasible intervention strategies from an economic and health perspective. Further applications could include providing information on the outcomes of improved treatment and disease management strategies. Since these approaches can lengthen life and possibly reduce costs, this information, combined with the effect on incidence, could offer insight into the combination of both treatment and prevention approaches.

The simplicity of this model does mean that several assumptions had to be made and must be acknowledged. First, the cost estimates are derived from a study that was based on Ontario data and thus the attributable costs used for national estimates assume that health care spending is similar in other provinces and territories. However, it is known that differences exist across jurisdictions, including within the general care and management of diabetes,[17] as well as in provincial coverage for services and products such as medications and assistive devices.[19,20] If province-specific attributable cost estimates did become available in the future, the cost calculation method could easily be adapted to include these region-specific costs.

Second, this method uses average attributable costs by sex and year of follow-up. As such, it cannot account for costs averted within specific subgroups, who may be using more or less health care than the average. For example, in an intervention aimed at a high-risk group, it is likely that these people spend more health care dollars than the average, but their averted cost calculated will not reflect this (i.e. it will be underestimated using this method). Efforts to produce estimates that are defined to more specific populations would enable more accurate estimates, particularly when modelling intervention scenarios for certain target groups.

Third, the model does not account for future changes in health care spending or inflation. It is assumed that diabetes case management will remain the same through 2022 and that current models of care will continue to be applied and used in the same way. Given the window of 10 years, this assumption is likely appropriate. Longer prediction periods would need to address potential changes to care and management.

Finally, our estimates do not account for the costs associated with diabetes that are not related to health care, including indirect costs, out-of-pocket costs and costs not captured in administrative databases, as well as emotional and social costs for patients and other caregivers. It is estimated that direct health care costs only account for 17% of total costs attributable to diabetes,[3] so it is crucial to consider these additional expenses in future research.

Conclusion

The goal of this work is to provide health decision makers with a readily usable tool that will allow them to make cost estimations up to 10 years in the future. Health planners and policy makers who focus on preventing diabetes at the population level can use this tool to evaluate different intervention strategies with customized incidence and cost predictions, which will assist them in determining the most appropriate actions for the future.

Acknowledgements

Dr. Laura Rosella is supported by a Canada Research Chair in Population Health Analytics. This work was supported by the Canadian Institutes of Health Research Operating Grant from the Institute of Nutrition, Metabolism and Diabetes (funding reference number 126615). The funders had no direct role in the analysis, interpretation, writing or submission of this manuscript.

Conflicts of interest

The authors disclose no conflict of interest.

Authors' contributions

LR conceived the manuscript. LR and AB contributed to analytic plan and interpretation. AB prepared data and ran all analyses. AB drafted the manuscript and LR edited and critically reviewed the final content.

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The burden of generalized anxiety disorder in Canada

Louise Pelletier, MD (1); Siobhan O'Donnell, MSc (1); Louise McRae, BSc (1); Jean Grenier, PhD (2,3)

This article has been peer reviewed.

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Abstract

Introduction: Although generalized anxiety disorder (GAD) is common and disabling, there are few Canadian studies on this mental illness. We compared the characteristics, health status, health services use and health care needs of Canadians with GAD to those with depression.

Methods: Data are from the 2012 Canadian Community Health Survey—Mental Health, which surveyed a nationally representative sample of Canadians aged 15 years and older (n = 23 709; response rate of 68.9%). The respondents we studied had self-reported symptoms compatible with GAD and/or major depressive episode (MDE) in the preceding 12 months (n = 1598). Estimates were weighted to represent the Canadian household population. We performed descriptive and multinomial multivariate logistic regression analyses.

Results: In 2012, an estimated 700 000 (2.5%) Canadians aged 15 years and older reported symptoms compatible with GAD in the previous 12 months. MDE symptoms co-occurred in 50% of these individuals. Those with GAD only reported fair/poor perceived health (29.7%), moderate to severe psychological distress (81.2%) and moderate to severe disability (28.1%) comparable to (or even slightly worse) than those with MDE only (24.7%, 78.8% and 24.8% respectively). Those with comorbid GAD and MDE demonstrated the worst health outcomes; 47.3% of them reported fair/poor perceived health, 94.0% reported moderate to severe psychological distress and 52.4% reported moderate to severe disability.

Nearly 50% of those with comorbid GAD and MDE reported that their need for health care was not met or only partially met, compared to about 30% of those with GAD or MDE only.

Conclusion: While GAD is associated with levels of distress and disability comparable to (or slightly worse) than those affected by MDE only, the health status of those with comorbid disease is significantly worse than those with GAD or MDE only. Improved diagnosis, screening for comorbidity and management are essential to minimize the impacts of this mental illness.

Keywords: *generalized anxiety disorder, impact, prevalence, disability, Canada, major depressive episode*

Highlights

- In 2012, an estimated 700 000 (2.5%) Canadians aged 15 years and older reported symptoms compatible with generalized anxiety disorder (GAD) in the previous 12 months, of whom 50% reported co-occurring symptoms compatible with a major depressive episode (MDE).
- While individuals with GAD only reported levels of fair/poor mental health, psychological distress and disability comparable to those affected by MDE only, those with comorbid GAD and MDE demonstrated significantly worse overall health outcomes.
- Nearly 50% of those with comorbid GAD and MDE reported that their need for mental health care was either not met or only partially met, compared to about 30% of those with GAD only or MDE only.

Introduction

In 2012, an estimated 2.4 million (or 8.7%) Canadians aged 15 years and older reported symptoms compatible with generalized anxiety disorder (GAD) during their lifetime. Among these individuals, 30% (or 2.6% of Canadians) reported symptoms in the 12 months preceding the survey.[1] This was the very first survey to provide national population estimates for GAD in Canada. Epidemiological studies using comparable methodology conducted in the United States, Europe and Australia found similar 12-month prevalence estimates (1%–4%).[2,3,4]

From a clinical perspective, individuals with GAD experience excessive anxiety and worry about a variety of topics (i.e. school, work and relationships), life events or daily activities. Worry occurs more days than not, for at least six months, and is clearly excessive and difficult to control.[5,6] In order to meet the diagnostic criteria for GAD, symptoms of excessive anxiety and worry must be associated with at least three of the following six symptoms in adults and at least one in children: restlessness, fatigue, trouble concentrating, irritability, muscle tension or sleep problems. The anxiety, worry or physical symptoms cause clinically significant distress or impairment in important areas of daily functioning, and the disturbance is not attributable to the physiological effects of a substance or another medical condition.[6]

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GAD usually begins in late adolescence or in the twenties; however, it can develop at any time of life.[7] A number of adults with GAD indicate that they have been worriers almost their entire life. Because excessive anxiety and worry is not clearly defined and is usually insidious in nature among those with early onset, it usually takes more than 10 years before a person is diagnosed.[7] On the other hand, those with a later onset, often related to a stressful life event, are more likely to consult a health professional within the first year of symptoms.[7] GAD has long been considered a chronic condition with waxing and waning of symptoms. However, a few recent longitudinal cohort studies showed that up to 50% of people with GAD could be symptom-free for extended periods of time, although a number of these individuals will relapse.[8,9,10] Higher levels of disability are more often associated with an earlier age of symptom onset and a longer duration of untreated symptoms.[10,11] In addition, the presence of comorbidities is associated with worse health outcomes.[6,8]

One of the main challenges in the early identification of GAD is that affected individuals rarely consult a health professional explicitly for excessive anxiety or worry.[12] They may instead consult for somatic symptoms such as fatigue, trouble sleeping, headaches, gastrointestinal symptoms or symptoms related to comorbidities.[5]

If symptoms are mild, a person with GAD may develop coping mechanisms, in which case their disorder will likely cause little interference with their daily functioning. In severe cases, however, a person with GAD may become seriously functionally impaired.[7]

GAD frequently co-occurs with other mental health disorders, thus making the diagnosis and treatment more challenging. Some studies have suggested that up to 90% of individuals with GAD present with comorbid mental disorders during their lifetime, including depression and other anxiety disorders.[4,12] GAD symptoms can also co-occur with chronic physical health problems such as chronic pain, diabetes and heart disease, and may exacerbate these physical illnesses or interfere with a person's ability to manage them.[13]

Until the last decade, there were doubts that GAD was an entity by itself because it so often presented to health professionals with other mental health disorders, particularly depression. However, a number of studies have since refuted this belief.[7,14] These studies have also found that the level of impairment among those with pure GAD was equivalent to that of pure major depression or other severely impairing physical diseases and conditions or mental disorders.[7,15,16] One of the key features of GAD is that while affected individuals rarely seek help for anxiety symptoms, they consume health care resources at a high rate, and account for a disproportionally high number of health care visits.[4,16,17]

Although depression has been widely studied, there is a paucity of epidemiological studies on GAD in Canada. Using data from a sample designed to be nationally representative of Canadians aged 15 years and older, our objectives in this study were (1) to compare the sociodemographic, behavioural and health characteristics of individuals with symptoms compatible with GAD (with or without comorbid MDE) in the preceding 12 months to those with MDE only; (2) to compare the health status, health services use and perceived need for health care among individuals with GAD (with or without comorbid MDE) to those with MDE only; and (3) to determine whether age differences exist in the associations between health status or health services use and these mental disorders.

Methods

Data source and study sample

The 2012 Canadian Community Health Survey—Mental Health (CCHS-MH) is a cross-sectional survey with a multistage stratified cluster sampling design covering the Canadian population aged 15 years and older living in the 10 provinces.[18] Exclusions include people living on reserves and Crown lands, homeless people, full-time members of the Canadian Forces and the institutionalized population, which together represent about 3% of the target population.

The purpose of the CCHS-MH was to collect information about mental health status, access to and perceived need for formal and informal mental health services and supports, overall functioning and disability, health determinants and sociodemographics.

The overall response rate for the CCHS-MH was 68.9%. For this study, we used the share file (n = 23 709) and excluded those respondents (n = 293) with missing responses to either GAD or MDE symptom-based measures, which resulted in a total study sample of 23 416.

More detailed information on the CCHS-MH, including the questionnaire, may be found at http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5015&Item_Id=119790&lang=en

GAD and MDE symptom-based measures

The CCHS-MH/World Health Organization Composite International Diagnostic Interview (WHO-CIDI) criteria are a modified version of the WHO-CIDI. The WHO-CIDI is a standardized instrument for the assessment of mental disorders and conditions according to an operationalization of the definitions and criteria of the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV).[19,20] It is designed to measure the prevalence of mental disorders at the community level, and can be administered by lay interviewers.

We considered respondents to have symptoms compatible with GAD if they met the CCHS-MH/WHO-CIDI criteria for GAD in the preceding 12 months.[18] Similar procedures were used to identify those with symptoms compatible with MDE in the preceding 12 months. See Box 1 for more information.

Sociodemographics

The sociodemographic characteristics we studied included sex (women, men); age (15–29, 30–49, 50+ years and mean age); marital status (single, divorced/separated/widowed, married/common law); respondent's highest level of education (less than secondary, secondary graduate, some post-secondary, post-secondary graduate); adjusted household income quintiles; employment status in the previous week (student, did not work including permanently disabled and elderly, worked); immigrant status (yes, no); Aboriginal status (yes, no); and geography (urban, rural).

To compute the adjusted household income quintiles, we divided respondents into income quintiles based on the adjusted ratio of their total household income to the low income cut-off corresponding to their household and community size, as derived by Statistics Canada.[21]

BOX 1

CCHS-MH/WHO-CIDI criteria for GAD, MDE and substance use disorder[21]

The 2012 Canadian Community Health Survey—Mental Health (CCHS-MH) used a modified version of the World Health Organization - Composite International Diagnostic Interview 3.0 (WHO-CIDI) to classify people with select mental or substance use disorders. Although this is not a clinical diagnosis, this is a standardized instrument that is typically used to assess mental disorders in population surveys according to the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) criteria.

Generalized anxiety disorder (GAD)

For the purposes of this survey, respondents who experienced the following CCHS-MH/WHO-CIDI **lifetime** criteria associated with generalized anxiety disorder reported

- excessive anxiety and worry and anxiety about at least one event or activity that lasted at least six months;
- finding it difficult to control the worry;
- the anxiety and the worry were associated with three or more of the symptoms associated with anxiety; and
- the anxiety, worry, or physical symptoms caused clinically significant distress or significant impairment in social, occupational, or other important areas of functioning.

For the purposes of this survey, respondents who experienced the following CCHS-MH/WHO-CIDI **12-month** criteria associated with generalized anxiety disorder reported

- meeting the criteria for lifetime generalized anxiety disorder;
- having an episode of generalized anxiety lasting at least six months in the 12 months before the interview; and
- clinically significant distress or impairment in social, occupational or other important areas of functioning.

Major depressive episode (MDE)

For the purposes of this survey, respondents who experienced the following CCHS-MH/WHO-CIDI **lifetime** criteria associated with major depressive episode, reported

- a period of two weeks or more with depressed mood or loss of interest or pleasure AND at least five additional symptoms;
- clinically significant distress or social or occupational impairment; and
- the symptoms are not better accounted for by bereavement.

For the purposes of this survey, respondents who experienced the following CCHS-MH/WHO-CIDI **12-month** criteria associated with major depressive episode

- met the criteria for lifetime diagnosis of major depressive episode (see above);
- reported an episode in the past 12 months; and
- reported marked impairment in occupational or social functioning.

Any substance use disorder (either dependence or abuse) in the past 12 months

"Any substance use disorder (either dependence or abuse) in past 12 months" refers to the use of any of the following: alcohol, cannabis, cocaine, club drugs, hallucinogens, heroin or opium, inhalant or solvent use, or nonmedical use of stimulants or analgesics. Respondents were defined as having symptoms compatible with a substance use disorder if they met the CCHS-MH/WHO-CIDI criteria for abuse or dependence of alcohol or drugs in the past 12 months.

- Dependence is characterized by a recurrent pattern of use where at least three of the following occur in the same 12-month period: increased tolerance, withdrawal, increased consumption, unsuccessful attempts to quit, a lot of time lost recovering or using, reduced activities and continued use despite persistent physical or psychological problems caused or intensified by substance use.
- Abuse is characterized by a recurrent pattern of use where at least one of the following occurs: failure to fulfill major roles at work, school or home; use in physically hazardous situations; recurrent alcohol related problems; or continued use despite social or interpersonal problems caused or intensified by alcohol. By definition, respondents who meet the criteria for substance dependence are excluded from meeting the criteria for substance abuse.

Behavioural and health characteristics

Smoking status was defined as "daily," "occasional/former" or "never." The number of physical comorbidities was based on self-reported, health-professional diagnosis of asthma, chronic obstructive pulmonary disease, arthritis, back problems, Crohn's disease, ulcerative colitis, diabetes, epilepsy, heart disease, cancer, stroke, Alzheimer's disease or any other dementia. Each disease was counted as a single physical comorbidity and the following three categories were reported: "none," "1 or 2" and "3 or more."

Respondents were considered to have symptoms compatible with a substance use disorder if they met the CCHS-MH/WHO-CIDI criteria for abuse of or dependence on alcohol or drugs in the past 12 months (Box 1).

Health status

Perceived health is an indicator of overall health status. Perceived health was measured by asking respondents "In general, would you say your health is excellent, very good, good, fair, or poor?" Suboptimal health status was defined as having "fair" or "poor" health.

Self-rated mental health was measured by asking respondents "In general, would you say your mental health is excellent, very good, good, fair, or poor?" Suboptimal mental health was defined as having "fair" or "poor" mental health.

"Level of psychological distress in the past month" was determined using the Kessler 6 (K6) instrument, which asks questions about feeling "nervous, hopeless, restless or fidgety, so depressed that nothing can cheer you up, everything was an effort and/or worthless" in the past month.[22] Scores range from 0 to 24 and are categorized as "no distress," "moderate" and "severe mental distress."[23]

"Level of disability in the last 30 days" was determined using the WHO Disability Assessment Schedule 2.0, which includes six domains of disability: cognition, mobility, self-care, getting along, life activities and participation. The overall score ranges from 0 (no disability) to 100 (full disability). Scoring is based on the recommended method outlined in the WHODAS 2.0 manual.[24] The categories were "no disability," "mild disability," "moderate disability" and "severe/extreme disability."[25]

Health professional consults, and perceived need for mental health care

Health professional consults for mental health issues in the past 12 months were determined by asking respondents if they had seen or talked on the telephone to any of the following people in the past 12 months about problems with their emotions, mental health or use of alcohol or drugs: psychiatrist; psychologist; family doctor or general practitioner; nurse; or social worker, counsellor or psychotherapist. Individuals were considered to have consulted a mental health professional in the past 12 months if they responded "yes" to the above question for psychiatrist, psychologist, social worker, counsellor or psychotherapist.

Overall perceived need for mental health care in the past 12 months was determined by grouping respondents into categories based on whether a need was reported (i.e. for information, medication, counselling or other), and if so, whether their needs were met, partially met or unmet.

Statistical analysis

To account for sample allocation and survey design, all estimates were weighted using survey weights generated by Statistics Canada to represent the Canadian household population aged 15 years or older in the 10 provinces in 2012.[18] Furthermore, variance estimates (95% CIs and coefficients of variation) were generated through bootstrap weights provided with the data.[26]

We performed cross-tabulation descriptive analyses to describe respondents reporting symptoms compatible with GAD only, comorbid GAD and MDE, and MDE only in the 12 months preceding the survey. Rao-Scott chi-square goodness-of-fit test and linear regression analysis were used to explore the relationship between categorical and continuous (i.e. mean age) respondent characteristics, respectively, and the aforementioned subgroups. Significance was defined as a p-value of $< .01$.

We used multinomial multivariate logistic regression analysis to compare the health status, health professional consults and perceived need for mental health care among those reporting symptoms compatible with GAD only, comorbid GAD and MDE versus MDE only in the past 12 months. Selected covariates were based on the literature and included sex, age, marital status, education level, household income quintiles, employment status, immigrant and Aboriginal statuses, smoking, alcohol and substance use disorder and physical comorbidities.[27,28]

Finally, we tested for interactions between age and the different health status and service use outcomes, adjusting for sociodemographic and health characteristic variables, for the specified mental disorders (i.e. GAD only, comorbid GAD and MDE, and MDE only). Significant models were determined by p-value $< .01$.

We performed the analyses with SAS Enterprise Guide version 5.1 (SAS Institute, Cary, NC, USA).

Results

Prevalence, sociodemographic, behavioural and health characteristics

Among Canadians aged 15 years and older, the prevalence of symptoms compatible with GAD in the preceding 12 months was 2.5%; about half of these individuals also reported symptoms compatible with MDE (Table 1).

The relationship between the subgroups of interest (GAD only, comorbid GAD and MDE, and MDE only) and the sociodemographic, behavioural and health characteristics studied were statistically significant for age and number of physical comorbidities only (Table 1).

Compared to those with MDE only, those with GAD only were older (mean age of 43.8 vs. 38.0 years), and more likely to have at least one physical comorbidity (65.9% vs. 49.0%). The latter finding is likely due to the confounding effect of age. Similarly, compared to those with MDE only, those with comorbid GAD and MDE were also slightly older (42.2 years) and more likely to have at least one physical comorbidity (68.4%).

Health status, health professional consults and perceived need for mental health care

Based on results from the subgroup analyses (GAD only, GAD and MDE, and MDE only), those with GAD only reported levels of fair/poor perceived health (29.7%), moderate to severe psychological distress (81.2%) and moderate to severe disability

TABLE 1
Sociodemographic and health characteristics of those with symptoms compatible with GAD only, comorbid GAD and MDE, and MDE only, household population aged 15 years and older, Canada excluding the territories, 2012

Sociodemographic and health characteristics	GAD only (n = 346; 1.2%)	GAD and MDE (n = 358; 1.3%)	MDE only (n = 894; 3.4%)	*p*-value
	% (95% CI)	% (95% CI)	% (95% CI)	
Sex				
Women	60.2 (52.6–67.7)	68.2 (60.7–75.7)	61.2 (56.2–66.3)	.23
Age				
Mean age (years)	43.8 (41.2–46.5)	42.2 (40.0–44.4)	38.0 (36.5–39.5)	< .001
Age groups (years)				
15–29	22.8 (17.2–28.4)	22.7 (15.9–29.5)	37.4 (32.2–42.6)	< .001
30–49	37.9 (30.8–45.1)	48.6 (40.5–56.6)	39.6 (34.1–45.2)	
50+	39.3 (31.6–47.0)	28.8 (22.3–35.3)	23.0 (19.3–26.7)	
Marital status				
Single	30.8 (23.9–37.7)	32.4 (25.3–39.4)	43.4 (38.1–48.6)	.05
Divorced/separated/ widowed	20.8 (14.0–27.6)	19.7 (14.1–25.4)	16.6 (11.9–21.2)	
Married/common-law	48.4 (40.3–56.6)	47.9 (39.7–56.1)	40.1 (34.9–45.3)	
Education (respondent)				
Less than secondary	15.0[E] (9.2–20.9)	18.2 (12.9–23.6)	18.2 (14.3–22.1)	.50
Secondary graduate	15.3[E] (9.1–21.4)	14.8[E] (9.4–20.3)	16.1 (12.6–19.6)	
Some post-secondary	6.5[E] (3.3–9.7)	11.7[E] (5.7–17.8)	11.8 (8.3–15.3)	
Post-secondary graduate	63.2 (55.5–70.9)	55.2 (47.6–62.8)	53.9 (48.6–59.2)	
Income quintile (household)				
1st	22.8 (17.0–28.6)	36.6 (28.5–44.6)	32.0 (26.8–37.2)	.07
2nd	21.6 (15.6–27.7)	25.5 (18.6–32.3)	21.9 (17.2–26.6)	
3rd	21.3[E] (14.0–28.7)	19.3[E] (12.8–25.9)	17.0 (13.3–20.6)	
4th	18.2[E] (11.7–24.8)	10.2[E] (6.1–14.3)	17.0 (13.2–20.8)	
5th	16.0[E] (10.0–21.9)	8.5[E] (4.5–12.4)	12.1 (9.0–15.2)	
Employment status				
Student	11.9[E] (7.9–15.9)	10.7[E] (6.4–15.0)	19.2 (15.3–23.2)	.03
Did not work	45.1 (37.3–52.8)	50.6 (42.1–59.1)	39.7 (34.1–45.2)	
Worked	43.0 (35.6–50.4)	38.7 (29.9–47.5)	41.1 (36.0–46.2)	
Immigrant status				
Immigrant	16.3[E] (9.2–23.4)	14.1[E] (7.7–20.4)	17.9 (13.4–22.4)	.65
Non-immigrant	83.7 (76.6–90.8)	85.9 (79.6–92.3)	82.1 (77.6–86.6)	
Aboriginal status				
Aboriginal	5.6[E] (2.6–8.6)	7.4[E] (3.3–11.4)	6.2[E] (3.2–9.2)	.80
Non-Aboriginal	94.4 (91.4–97.4)	92.6 (88.6–96.7)	93.8 (90.8–96.8)	
Geographic area				
Rural	18.3[E] (12.2–24.3)	17.1 (11.6–22.5)	13.3 (10.2–16.4)	.19
Urban	81.8 (75.8–87.8)	82.9 (77.5–88.4)	86.7 (83.6–89.8)	

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(28.1%) comparable to (or even slightly worse than) those with MDE only (respectively, 24.7%, 78.8% and 24.8%). However, those with comorbid GAD and MDE demonstrated worse health status, irrespective of the measure studied, compared to those affected by MDE only. About half of the comorbid group reported suboptimal perceived health, dissatisfaction with life and severe psychological distress; more than two-thirds reported suboptimal mental health; and nearly one-quarter reported severe or extreme disability. The relationship between the subgroups of interest and all health status measures were statistically significant (Table 2).

Interestingly, less than 60% of individuals with GAD only or with MDE only consulted a health professional, while nearly 75% of those with comorbid GAD and MDE indicated having consulted. Similarly, a greater proportion of individuals with comorbid GAD and MDE had consulted a mental health professional (40%), compared to those with MDE only (about 30%) and those with GAD only (nearly 25%).

When asked whether their need for mental health care was met or not, about 30% of individuals with GAD only and MDE only reported that their needs were either partially met or not met at all, compared to nearly 50% of those with comorbid GAD and MDE. The relationships between the subgroups of interest and health professional consults or perceived need for care were all statistically significant (Table 3).

Finally, upon controlling for all sociodemographic, behavioural and health characteristics, all health status measures studied were similar (or worse, in the case of moderate disability level) for those with GAD only compared to those with MDE only (Table 4). However, those with comorbid GAD and MDE were about 2.5 times more likely to report fair/poor mental health, 8 times more likely to report severe psychological distress, and nearly 10 times more likely to experience severe levels of disability compared to those with MDE only. Also, they were about 2 times more likely to report their need for care was either partially met or not met at all.

We observed no significant age-related effects (data not shown).

As expected, those with GAD (with or without MDE) demonstrated significantly

TABLE 1 (continued)
Sociodemographic and health characteristics of those with symptoms compatible with GAD only, comorbid GAD and MDE, and MDE only, household population aged 15 years and older, Canada excluding the territories, 2012

Sociodemographic and health characteristics	GAD only (n = 346; 1.2%)	GAD and MDE (n = 358; 1.3%)	MDE only (n = 894; 3.4%)	*p*-value
	% (95% CI)	% (95% CI)	% (95% CI)	
Smoking status				
Daily	22.0 (15.9–28.1)	33.0 (25.8–40.1)	26.0 (21.5–30.4)	.04
Occasional/former	33.7 (26.7–40.8)	38.7 (31.0–46.4)	40.7 (35.7–45.6)	
Never	44.3 (36.1–52.4)	28.4 (20.6–36.1)	33.4 (27.7–39.1)	
Substance use disorder				
Yes	10.2[E] (6.1–14.3)	17.6[E] (11.8–23.3)	16.0 (11.7–20.2)	.12
No	89.8 (85.7–93.9)	82.4 (76.7–88.2)	84.0 (79.8–88.3)	
Physical comorbidities				
3+	18.1[E] (11.0–25.3)	19.3 (13.1–25.5)	8.6 (6.1–11.1)	< .001
1–2	47.8 (39.9–55.8)	49.2 (41.3–57.1)	40.4 (35.3–45.6)	
None	34.1 (26.9–41.2)	31.6 (23.5–39.7)	51.0 (45.7–56.2)	

Abbreviations: CI, confidence interval; GAD, generalized anxiety disorder; MDE, major depressive episode.

Notes: n are based on unweighted numbers and proportions (%), means and 95% CIs are based on weighted data.

This table only presents data of the last 12 months (n = 1598).

[E] High sampling variability (coefficient of variation between 16.6–33.3%).

TABLE 2
Health status factors for those with symptoms compatible with GAD only, comorbid GAD and MDE, and MDE only, household population aged 15 years and older, Canada excluding the territories, 2012

Health status factors	GAD only (n = 346; 1.2%)	GAD and MDE (n = 358; 1.3%)	MDE only (n = 894; 3.4%)	
	% (95% CI)	% (95% CI)	% (95% CI)	*p*-value
Perceived health				
Fair/poor	29.7 (22.2–37.2)	47.3 (39.4–55.1)	24.7 (20.2–29.2)	< .001
Self-reported mental health				
Fair/poor	44.7 (36.8–52.6)	69.9 (62.8–77.0)	45.3 (40.1–50.5)	< .001
Psychological distress in the past month				
Severe	17.8[E] (11.4–24.2)	51.1 (43.5–58.7)	19.4 (15.0–23.7)	< .001
Moderate	63.4 (55.4–71.4)	42.9 (35.1–50.7)	59.4 (54.1–64.7)	
None	18.8[E] (12.3–25.4)	6.0[E] (2.9–9.1)	21.2 (17.3–25.2)	
Disability in the last 30 days				
Severe/extreme	NR	22.2 (15.6–28.8)	6.0 (4.2–7.9)	< .001
Moderate	28.1 (19.5–36.7)	30.2 (22.7–37.6)	18.8 (15.0–22.5)	
Mild	47.8 (39.2–56.4)	37.5 (29.4–45.5)	43.4 (38.0–48.8)	
None	19.3 (13.2–25.5)	10.2[E] (5.5–14.9)	31.8 (26.8–36.9)	

Abbreviations: CI, confidence interval; GAD, generalized anxiety disorder; MDE, major depressive episode; NR: not reportable (coefficient of variation higher than 33.3).

Notes: n are based on unweighted numbers and proportions (%) and 95% CIs are based on weighted data.

This table only presents data of the last 12 months (n = 1598).

[E] High sampling variability (coefficient of variation between 16.6–33.3%).

worse perceived health, self-rated mental health, psychological distress and disability levels compared to those with neither GAD nor MDE. Similarly, those with GAD (with or without MDE) were more likely to consult a health professional for their mental health symptoms and their perceived need for mental health care was greater than those without GAD or MDE (data not shown; available upon request from the authors).

Discussion

In 2012, an estimated 700 000 (2.5%) Canadians aged 15 years and older were affected by symptoms compatible with GAD, with half of these individuals presenting with comorbid MDE symptoms. These estimates may be conservative considering that those affected by GAD (and MDE) have poorer self-reported health and self-reported mental health, and it has been shown that nonresponders have a significantly higher proportion of poor self-rated health even with consideration given to sex, age, country of birth and level of education.[29] However, to our knowledge, the issue of nonresponse bias among those with different types of mental disorders, such as GAD and MDE, has yet not been studied.

This study highlights the fact that those affected by GAD only reported similar (or even slightly worse) ratings in terms of perceived health, self-reported mental health, psychological distress and disability to those affected by MDE only, as shown elsewhere.[3,7,16,30]

It also demonstrates poorer health-related outcomes among those affected by comorbid GAD and MDE, as well as the considerable limitations in daily life associated with those disorders as evidenced by a high level of disability. These findings support the results of other studies on comorbid anxiety and depression.[3,7,12,31-35] Therefore, health professionals encountering individuals with either anxiety or depressive symptoms should carefully assess for the presence of comorbid psychological conditions. In addition, considering that nearly 70% of those with comorbid GAD and MDE had at least one physical chronic condition, and in light of solid evidence elucidating the bidirectional relationship between mental illnesses (specifically depression and anxiety) and physical health outcomes,[36] particular attention should be given to the prevention

TABLE 3
Health professional consults and overall perceived need for care for those with symptoms compatible with GAD only, comorbid GAD and MDE, and MDE only, household population aged 15 years and older, Canada excluding the territories, 2012

Consults and perceived need	GAD only (n = 346; 1.2%) % (95% CI)	GAD and MDE (n = 358; 1.3%) % (95% CI)	MDE only (n = 894; 3.4%) % (95% CI)	*p*-value
Health professional consults in the past 12 months				
Yes	56.2 (48.7–63.6)	72.7 (64.9–80.4)	59.9 (54.8–65.1)	.008
Mental health professional consults in the past 12 months				
Yes	33.0 (26.0–40.0)	52.6 (44.4–60.9)	42.7 (37.3–48.1)	.003
Overall perceived need for health care in the past 12 months				
None	26.0 (18.4–33.7)	8.6[†] (3.6–13.5)	22.5 (18.5–26.6)	< .001
All met	43.3 (34.7–51.9)	42.9 (34.3–51.6)	45.7 (40.2–51.3)	
Partially met/not met	30.7 (23.4–37.9)	48.5 (40.3–56.8)	31.8 (26.9–36.6)	

Abbreviations: CI, confidence interval; GAD, generalized anxiety disorder; MDE, major depressive episode.
Notes: n are based on unweighted numbers and proportions (%) and 95% CIs are based on weighted data.
This table only presents data of the last 12 months (n = 1598).
[†] High sampling variability (coefficient of variation between 16.6–33.3%).

TABLE 4
Adjusted odds ratio of having symptoms compatible with GAD only or comorbid GAD and MDE versus MDE only, by health status, health professional consults and overall perceived need for care, household population aged 15 years and older, Canada excluding the territories, 2012

		OR (95% CI)
Perceived health		
Fair/poor vs. excellent/very good/good	GAD only	1.2 (0.7–2.0)
	GAD and MDE	1.9 (1.1–3.3)
	MDE only	Referent
Self-reported mental health		
Fair/poor vs. excellent/very good/good	GAD only	1.2 (0.8–1.8)
	GAD and MDE	2.6 (1.6–4.1)
	MDE only	Referent
Psychological distress in the past month		
Severe vs. none	GAD only	1.8 (0.9–3.6)
	GAD and MDE	7.9 (3.5–17.5)
	MDE only	Referent
Moderate vs. none	GAD only	1.8 (1.0–3.0)
	GAD and MDE	2.4 (1.2–5.0)
	MDE only	Referent
Disability in the last 30 days		
Severe/extreme vs. none	GAD only	1.4 (0.5–4.1)
	GAD and MDE	9.8 (4.0–23.9)
	MDE only	Referent
Moderate vs. none	GAD only	2.3 (1.3–4.3)
	GAD and MDE	4.9 (2.3–10.4)
	MDE only	Referent
Mild vs. none	GAD only	1.8 (1.0–3.1)
	GAD and MDE	2.9 (1.4–5.7)
	MDE only	Referent

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and management of comorbid chronic physical illnesses.

Furthermore, this paper demonstrated that nearly 50% of those with comorbid GAD and MDE perceived that their need for mental health care was either not met or only partially met compared to about 30% of those with GAD only or MDE only. While this study did not allow us to estimate the proportion of individuals with GAD being adequately diagnosed and treated, studies have shown that GAD is usually poorly recognized[4,16] and that up to two-thirds of patients suffering from anxiety disorders do not receive evidence-based treatments.[30,33,37]

Strengths and limitations

This study has a number of strengths, including the large, population-based sample and the administration of the survey by trained personnel using a structured format.

However, our findings should be interpreted in light of some important limitations. First, the results are based on self-reported data, which is sensitive to social desirability bias, recall bias and conscious nonreporting. Second, the relatively low response rate of 68.9% is of concern. It could be assumed that those affected by mood and/or anxiety disorders, particularly those with more severe symptoms and poor perceived health,[29] may be more reticent or ambivalent about participating in such a survey. Consequently, our results may underestimate the true prevalence of these disorders and may be influenced by those who responded, a type of participation bias. While it should be noted that Statistics Canada weighting adjustment strategies help mitigate the impact of overall nonresponse, this may not have had an impact on this particular nonparticipation bias. Third, the disorder type results are based on WHO-CIDI criteria and not on a clinical assessment by a mental health professional. Finally, the results we observed are based on a cross-sectional design; therefore, it is not possible to determine whether the associated factors contributed to the development of GAD and/or MDE or were a consequence of it.

Conclusion

GAD is common, frequently co-occurs with MDE and can profoundly impact the lives

TABLE 4 (continued)
Adjusted odds ratio of having symptoms compatible with GAD only or comorbid GAD and MDE versus MDE only, by health status, health professional consults and overall perceived need for care, household population aged 15 years and older, Canada excluding the territories, 2012

		OR (95% CI)
Health professional consults in the last 12 months		
Yes vs. no	GAD only	0.8 (0.6–1.3)
	GAD and MDE	1.6 (1.0–2.6)
	MDE only	Referent
Mental health professional consults in the past 12 months		
Yes vs. no	GAD only	0.8 (0.5–1.2)
	GAD and MDE	1.4 (0.9–2.3)
	MDE only	Referent
Overall perceived need for health care		
Partially met/not met vs. all met	GAD only	1.4 (0.8–2.3)
	GAD and MDE	1.8 (1.1–3.0)
	MDE only	Referent

Abbreviations: CI, confidence interval; GAD, generalized anxiety disorder; MDE, major depressive episode; OR, odds ratio.

Notes: ORs and 95% CIs are adjusted for sex, age, marital status, education (respondent), income quintiles (household), employment status, immigrant status, Aboriginal status, geographic region, smoking status, substance use disorder and physical comorbidities, and are based on weighted data.

This table only presents data of the last 12 months (n = 1598).

of those affected. While those affected by GAD show similar, or even slightly worse, levels of perceived health, psychological distress and disability to those affected by MDE only, individuals affected by both disorders demonstrated worse health outcomes. Similar to depression, initiatives to improve the recognition and management of GAD and comorbid GAD and MDE are needed to help decrease the severity and persistence of symptoms, and to prevent the onset of secondary mental health disorders or physical chronic diseases.

Acknowledgements

This research received no specific grant from any funding agency, or commercial or not-for-profit entities.

Conflicts of interest

None to report.

Authors' contributions

All authors conceptualised the study, SO analysed the data and LP drafted the paper. All authors contributed to the interpretation of the data and provided comments to the draft paper.

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